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Dental implants analysis by means of Video Image Correlation method

Daniel-Tamas Szava^{a,*}, Balint Bogoz^a, Botond-Pal Galfi^b, Ioan Szava^b, Raluca Dora
Ionescu^b, Renata Ildiko Munteanu^b

^aUniversity of Medicine and Pharmaceutics Tirgu-Mures, Faculty of Dental Medicine, 38 Gh. Marinescu str., Tirgu-Mures, 540139, Romania

^bUniversity Transylvania of Brasov, Faculty of Mechanical engineering, 29 Blvd. Eroilor, Brasov, 500036, Romania

Abstract

In this contribution, the authors are offering useful details on a non-contact, experimental investigation tool, namely: the VIC-3D optical system. The facilities of this system are allowing its implementation in the dental practice, more exactly in the dental implants optimization from stress-strain state point of view.

They describe an original testing bench, destined to evaluate the strain-field in the vicinity of the dental implants mounted in some artificial mandibles, obtained by Rapid Prototyping.

Finally, there are illustrated the experimental approach facilities by mean of some preliminary results.

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1. Introduction

Based on the importance of the dental implantology, the authors started some high-accuracy investigation in order to optimize their positioning. By means of an optimal positioning of the implants, the mastication will also be improved.

* Corresponding author. Tel.: +4-074-796-6136.

E-mail address: szavadani@yahoo.com

The implant durability, among other parameters, depends on the vertical and horizontal amount of surrounding fixing bone substrate. In the unsuccessful cases due to peak tensions, there appears resorptions and lyses of the bone surrounding the dental implant.

The authors aim to analyze, by means of a modern optical non-contact experimental method: the Video Image Correlation (VIC), the biomechanical phenomena and strain distribution, occurring inside the fixing substrate, given by the different stages of deterioration of the fixing substrate surrounding the dental implant.

In this contribution are presented the experimental system facilities, the original conceived experimental stand, respectively some preliminary results.

2. The proposed investigation method

The authors, based on their previous experience, started these investigations involving a modern, non-contact optical method: the VIC [1, 2, 3]. Its 3D version, from ISI-Sys GmbH, Kassel, Germany (system producer) and the Correlated Solution Company, USA (software producer) [4, 5, 7].

This system offers both the displacement field and the corresponding strain field along all three coordinate axes with the same accuracy (up to $1\ \mu\text{m}$).

One can also mention that the system practically eliminates all disadvantages and limitations of the most used, classical, experimental methods.

Mainly, the system consists of two video cameras, fixed on a very rigid Aluminium rod, mounted on a very stable and rigid tripod (fig.1). Depending on the required accuracy, these cameras can be with 1.5 10 *Mpixels* resolution.

Among the main advantages of the system, can be mentioned that its software eliminates the rigid body movements from the acquired images and consequently it can be applied, not only in high-accuracy vibration insulated laboratory conditions, but also in normal working conditions.

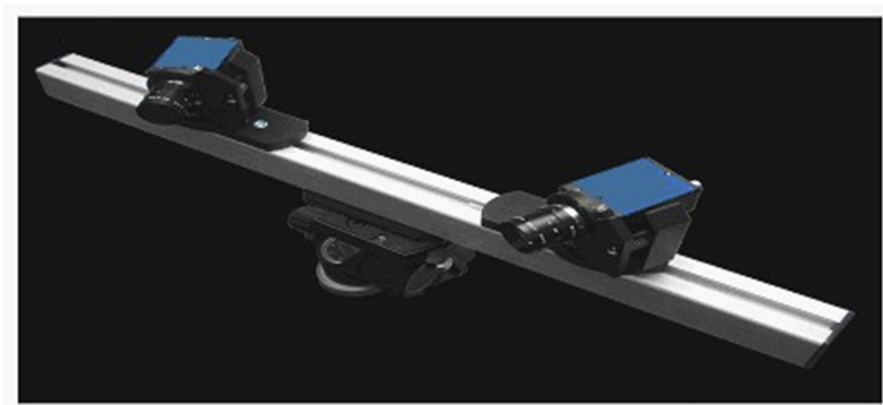


Fig. 1. The VIC-3D setup [4, 5].

The preparation of the tested object/specimen consists in spraying it with a water-soluble paint, in order to obtain a non-uniform dotted surface. The dots will present an arbitrary size, shape and emplacement. In order to obtain a good contrast of the dots, the surface will be coloured in advance with an opposite coloured paint (e.g.; if one has to apply black paint for the dots, than the primer has to be a non-reflecting white colour one and vice-versa). In this way one can assure different grey-intensity of each pixel from the tested surface.

The next step of the experiments consists in an adequate calibration, using some special targets (plates provided with a well-defined and high-accuracy positioned set of dots).

The calibration target will be positioned in the place of the prospective object and will be rotated in space (Figure 2).

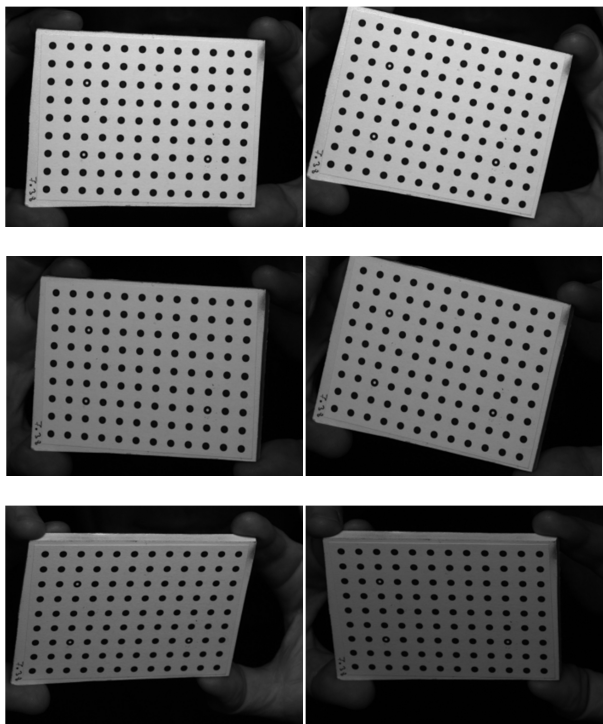


Fig. 2. Different stages of the calibration process of each camera.

Consequently, the software will be able to identify (with high-accuracy) the eloquent dots in 3D positioning, as it is shown in Figure 3.

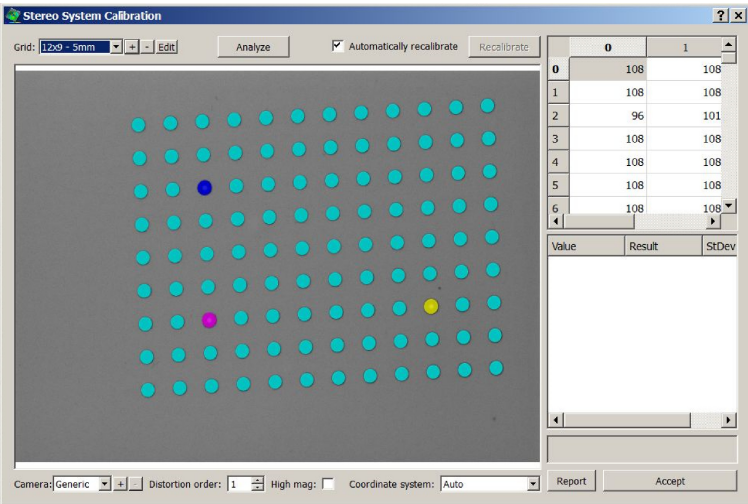


Fig. 3. The extraction of the calibration points for the stereo calibration.

After the calibration, the tested object will be placed in the determined position and the two cameras will perform the image acquisition in a $[n*m]$ matrix of pixels.

This acquisition will be performed firstly for the unloaded state (where one has to define *the area of interest*) and after: for the loaded one.

Each captured image (by these two cameras), corresponding to the initial state of the object (more exactly: only the predefined area of interest), will be analyzed step-by-step (based on the schematic diagram from Figure 4).

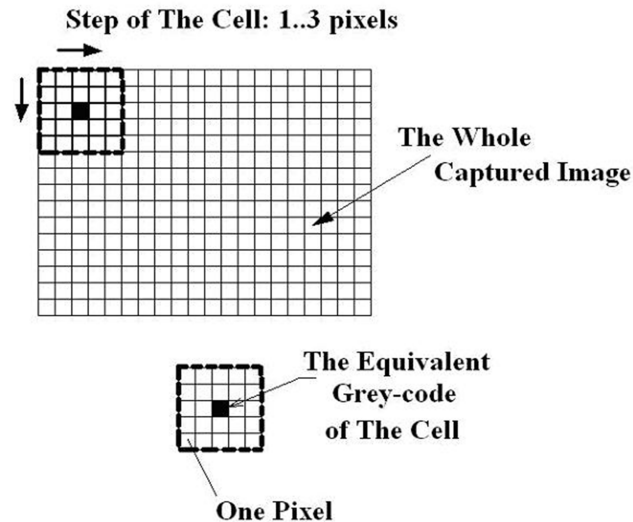


Fig. 4. The measuring principle based on the scanning procedure [6].

In this respect, the program allows the pre-selecting of a Subset (primary cell) sizes (here: $5.5=25$ pixels), respectively the step-magnitude (step size) for moving/translation of the Subset in horizontal and vertical direction). For this Subset the program will establish a unique grey-code, correlated to its median pixel high-accuracy 3D positioning.

By analyzing the whole image (by crossing over it with a pre-selected step: a number of pixels), each Subset cells will obtain a nominated (unique) high-accuracy spatial positioning and also a unique grey-code, too.

After loading the tested specimen, for all captured images (only in the area of interest, of course!), the program will identify the new positions of these Subsets, by performing an adequate comparison.

In order to perform an adequate analysis of the captured images, the software requires, on the reference state, one single point (I mean: one Subset) identification on the left and right captured images; based on this single identification, the software will perform the identification of all Subsets in all captured image-pairs.

For establishing the requested displacements, strains, as well as the corresponding main strains, one can select not only singular points, but also lines, curves, or small rectangles (the so-called “virtual strain gauges”, similarly with the electrical strain gauges rosettes); these lines, and curves will have a desired number of constitutive points, along which the program computes the 3D displacements, adequate strains and main strains.

The acquired data (set of images) can be re-analyzed as many times as one wish (with other lines, curves, or with other virtual strain gauges) and consequently, one assures a repeatability of identical initial conditions of the performed experiment.

Does not require expensive consumables, only some water-soluble paints (black and white), which can be easily cleaned after the experiments.

Being a contact-less method:

- during the investigations there is no influence on the analysed phenomenon;

- it can be applied to a large sort of materials (homogeny, un-homogeny, isotropy, orthotropy, anisotropy), like metals, human bones, human tissues, wood-based materials, plastics, or composites.

Other significant advantage of this system consists in its potential, allowing a very high-accurate analysis (practically pixel-by-pixel) of the investigated surface, which cannot be guaranteed in the classical experimental methods. This evaluation accuracy can be improved by selecting a zoomed viewing area, respectively using higher accuracy cameras.

Also, the software of VIC-3D offers the facility of monitoring the obtained results, either in color graph (similarly with the FEM analysis results), either can be exported in Excel-files, destined for drawing-up several useful graphs.

In order to offer validation opportunities for numerical analysis of the analyzed body (i.e. to validate their numerical models), the VIC-3D results (the displacement field and the strain field from the investigated surface) can serve as input data for Boundary Element Method, respectively for Finite Elements Method, due to the fact, that there is the facility to perform a meshing of the area of interest with a requested density (which can be fitted to the numerical analysis mesh-density).

These facilities represent incontestable advantages of the VIC, together with its 3D high-accuracy evaluation of the displacements.

Consequently, according to the authors' opinion, this experimental method will serve in the next period as a very useful tool also in dental investigations.

3. The original testing bench

The authors designed an original testing device in order to monitor the displacements and strains, which are produced in the artificial mandible during the mastication simulation.

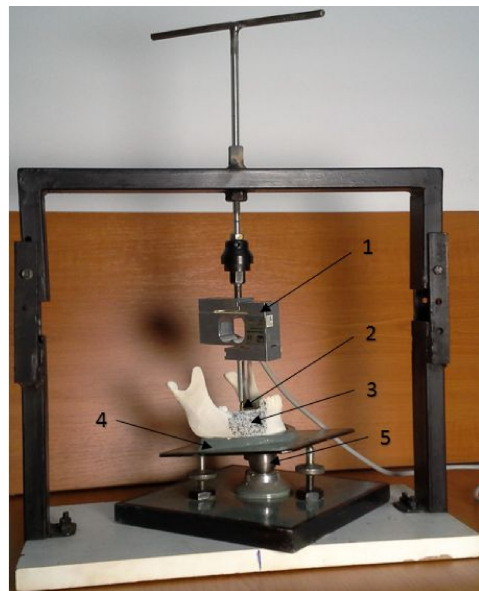


Fig. 5. The testing bench.

The main components of this bench are: the load cell 1, which monitors the real load magnitude (applied either by means of an universal tensile-compression machine, either by means of a special loading frame); a special screw, fixed into the lower part of the load cell, which acts on the implant upper part 2; the artificial mandible 3, obtained by Rapid Prototyping, which is lying in a special hard plastic material bed, casted on the plate 4; a revolving back 4, which 3D positioning are assured by mean of three adjustable screws and a central spherical part 5. These latter

components are lying in some corresponding hemi-spherical beds (all included in a rigid steel plate), which allows them to be smoothly adjusted. The central spherical part presents in its upper side a fixing screw, in order to fix the obtained rotated positioning of the plate 4 by means of the different lengths of the screws 5. Consequently, during the loading of the mandible, the system will present a stable spatial positioning.

In figure 6 is shown the whole assembly, consisting of loading frame 1, the VIC system 2, respectively the eight-channels electric strain gauge measuring unit 3.

Before the experiments, the fixing screw of the spherical central part is discharged of load/stress relieved in order to allow an easy 3D-positioning of the plate 4, by means of the three adjustable screws 5 (see figure 5). After a precise 3D-positioning of the plate 4, the above-mentioned fixing screw is tightened. Consequently, one can obtain an adequate 3D-positioning of the implant in relation with the load cell vertical position, and hence an adequate mastication force direction on the implant. The original testing bench allows rotations of the plate 4, in order to obtain various mastication directions (approximately $\pm 30^\circ$ compared to the vertical direction).

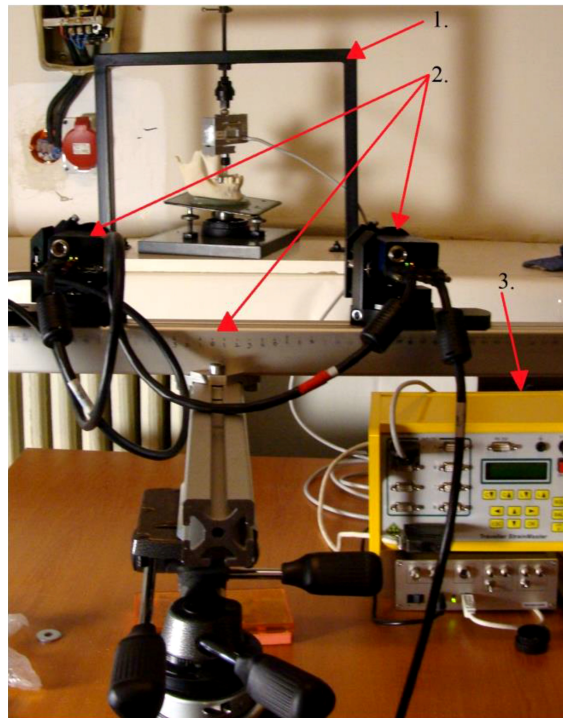


Fig. 6. The assembly of the measuring system.

4. Some preliminary results

The authors have received some artificial mandibles, obtained through Rapid Prototyping, from ABS plastic material, in which were fixed, in different locations cylindrical-conical screw-type implants from *Protetim Plus*, Hungary. The maximal load was up to 800 N, a little bit over passing the normal mastication forces (600 N).

In figure 7 is illustrated the VIC system displacement evaluation, with the preselected 12 points, disposed in the axis of the implant, respectively symmetrically positioned for the adjacent premolars.

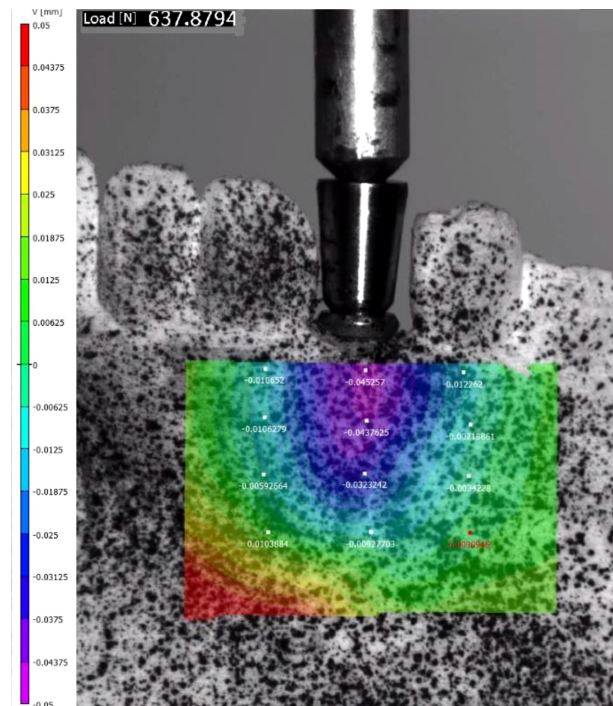


Fig. 7. The vertical displacement field with the preselected 12 points, disposed in the axis of the implant, respectively symmetrically disposed positions at the adjacent premolars.

Figure 8 offers an illustrative comparison of the vertical displacements of the fixing substrate (at the level of the 2nd point in the implant axis), related to different angular positioning of the load at 0°; 10°; 15°; 20°.

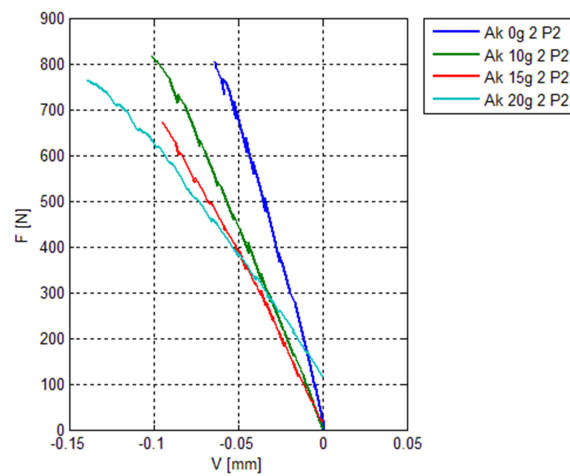


Fig. 8. The comparison of the vertical displacements of the fixing substrate (at level of the 2nd point in the implant axis, related to different angular positions of the load at 0°; 10°; 15°; 20°.

5. Conclusions

The authors developed an original testing bench in order to evaluate the displacements and the strains in the implant vicinity, related to different directions of the mastication force.

The preliminary tests were performed using some artificial mandibles, obtained by Rapid Prototyping from ABS plastic material.

The experimental set-up was based on the VIC-3D system, which proved its efficiency in these non-contact monitoring.

The authors express their faith that the above-presented VIC system will become soon a common tool in dental implants investigations.

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